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Overview of Selected Freshwater Aquatic Toxicology Research in the U.S. EPA (Environmental Protection Agency)

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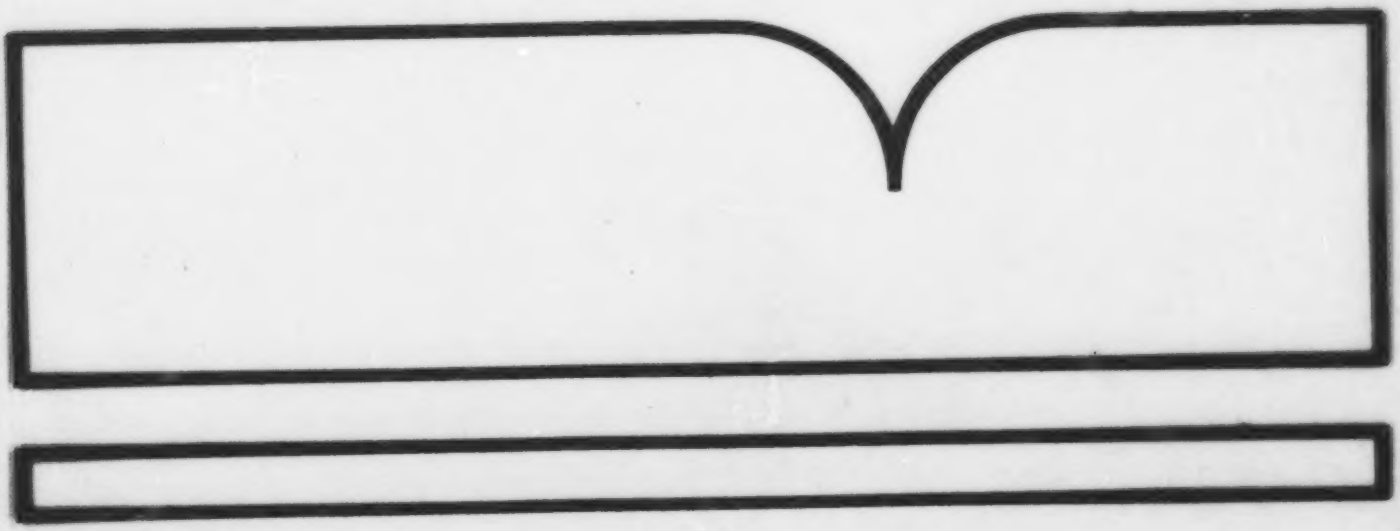

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OVERVIEW OF SELECTED FRESHWATER AQUATIC TOXICOLOGY RESEARCH IN THE U.S. EPA

by

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EPA research priorities in aquatic toxicology are established by Agency initiatives. Much emphasis is now directed towards shorter, faster toxicity test methods for pre-market registration of new chemicals and on whole effluent tests to be used as NPDES Permits. More attention is expected to be given to incorporating the regulatory strategy to be used with the development of water quality criteria limits.

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Overview of Selected Freshwater Aquatic Toxicology Research in the U.S. EPA.

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Aquatic toxicology research emphasis in the U.S. EPA is based to a very large extent on the regulatory needs and activities of the rest of the Agency which in turn is largely determined by legislative mandates and environmental emergencies. For aquatic toxicity research, the Toxic Substances Control Act and the Clean Water Act provide the largest needs for research effort with lesser impetus from other acts such as the Federal Insecticide, Rodenticide and Fungicide Act. The concern over acidic atmospheric deposition is an example of an environmental problem which has stimulated considerable aquatic toxicology effort.

Under the Toxic Substances Control Act (TSCA) EPA cannot specify tests which must be performed for premarket notification of new chemicals. A group of test standards (the name used for test protocols) have been developed that include a number of aquatic toxicity tests. Because the premarket notification step must be done well before the economic success of a chemical is assured, test protocols that are quick and, therefore, also cheaper, are very desirable. These needs focus research towards easier and quicker tests, especially for chronic toxicity; ones that will allow more complete toxicity data to be developed at a lesser price. Also, the data base of aquatic toxicity has been examined to identify the best species for predicting community effects since only a few species will be tested. Since decisions about safety must be made before the chemical is in the environment, field studies cannot be used as a method of evaluation.

Because, thus far, PMN's (premarket notification) have not contained as much aquatic toxicity data as desired, Quantitative Structure Activity Relations (QSAR) are being used to make initial decisions about the need for more aquatic toxicity data before approval is given or denied. A large effort has been mounted over the past few years to build a data base to support or refute the validity of such estimates of toxicity. The concensus of those largely responsible for the program, is that if the mode of action is known, the QSAR prediction will be useful. Some current effort is being directed towards methods to more easily determine the mode of action through physiological and biochemical approaches.

Also, for use in TSCA activities, a large data base of biological and chemical-physical data on thousands of chemicals has been assembled. One unique feature of this data base is the capability to provide an estimate of the bioconcentration factor (either measured or calculated) for more than 50,000 chemicals. High bioconcentration potential is considered a "red flag" characteristic for a new chemical.

Several needs of the Clean Water Act (CWA) require aquatic toxicity research. While many of the research methods and approaches are similar to those for other needs, the specific application of data is rather dissimilar requiring different lines of detailed study. Only two of these, water quality criteria and whole effluent toxicity control, will be discussed here.

As a result of court action, EPA was required to prepare criteria documents for 129 single or groups of chemicals, metals or mixtures. These are commonly called the priority pollutants. A rather massive literature search was made to locate existing toxicity data in the world literature for use in preparing these criteria documents. The job was clearly far too large for

one person to do, so a group of several people prepared the first drafts. A review of these drafts made clear that each author used different judgment in synthesizing the data, employed different margins of uncertainty and felt different amounts or types of data were necessary to set a criterion. Such differences were undesirable from an Agency perspective.

A set of guidelines were developed by a committee of six aquatic toxicologists with the purpose of systematizing the use of aquatic toxicity data to arrive at a water quality criterion[1]. The objective was to develop complete enough rules so that several different people using the same data base would arrive at the same criterion.

Since there was not time or resources to generate new data, the existing types of data had to be used for developing criteria. The data generally fell into one of three major types: 1) acute lethality data, 2) chronic reproductive data, and 3) miscellaneous physiological, behavioral or biochemical data. Furthermore, most of the existing data included only a few species of organisms.

The committee established a minimum data base requirement consisting of acute toxicity data for eight genera of aquatic organisms, and chronic toxicity data for three species. Guidance is provided for what taxonomic groups must be included within the minimum data set. Rules to calculate a bioconcentration factor (BCF) were also agreed upon as well as how to use the BCF to arrive at a water exposure. A decision was made to use the 95% confidence level for the degree of protection when extrapolating to larger numbers of species.

Finally, the criterion recommended was a two part one consisting of a maximum not to be exceeded and an average concentration which also must be met. Subsequent to the committee's formulation of these rules, design

personnel pointed out the necessity to also specify a violation frequency in order to use the criteria for design of waste treatment facilities. At this writing, the frequency of violation has not yet been agreed upon but the concensus is that it should be based on ecosystem recovery time and that an ecosystem should not always be in a state of recovery.

The development of these guidelines made several important matters obvious. The necessity of specifying a minimum data set from which to set a "safe" level was an exercise needed for us aquatic toxicologists. Never before had we forced ourselves to reveal how much of what kind of data we really do need to set a criterion. Having now done so, even if incorrect, we have a focus around which data can be generated more cost-effectively and if some of the decisions are wrong, the wide use of them will result in the errors being more likely recognized and corrected. The rules provide a "model" which greatly aids in helping to see better what data we do need or how we need to change our views.

These guidelines in conjunction with the assembled and formatted data, allow one to use the existing data to see relationships such as which species appear to be most useful as test animals and what types of tests are most cost-effective for decision making. The involvement of toxicologists in applying toxicity data in regulatory programs emphasized the tremendous importance the regulatory strategy has in changing the margin of safety of a given criterion. For example, if a given criterion number must be met at the very lowest flows that infrequently occur in a stream, the degree of protection afforded by that number is much higher than if it only needs to be met at flows that occur much more often. The hydrologic condition to which a criterion is applied may have more bearing on the exposure occurring than whether the criterion is based on acute or chronic data.

After criteria were derived using this methodology some people concerned about criteria values felt that an option should be available to adjust criteria values to site-specific situations. Most frequently mentioned was that the species for which test data were available were not found locally and might not be representative of the sensitivity of local species. Secondly, different water quality characteristics in local situations might change the criteria values. In response to these issues, a site-specific protocol was established which retained the basic philosophy of the original guidelines but allowed for species substitution and adjustment for water quality effects. So far, in the few instances where site-specific criteria have been derived, the magnitude of change has been relatively small due to species differences and from 5-10 times different due to water type.

Data were sufficient to derive criteria for only 12 or 15 chemicals. These plus non-priority pollutants for which criteria already existed only summed to criteria for 25 or 30 pollutants. Because of the growing concern for toxic chemicals, the EPA began to search for other ways to more rapidly develop limits for discharge of the many other chemicals in use.

In March of 1984, a policy was adopted and published in the Federal Register by EPA stating, among other things, that EPA was going to emphasize impact of discharges on receiving water in issuing the next round of discharge permits, and that limitations on toxicity of effluents was going to be used in addition to limits on single chemicals[2]. That is, toxicity would be considered as an effluent characteristic to be controlled (without requiring identification of the cause of toxicity) much in the way BOD is controlled (for which the cause is not identified either).

A rather large effort has been made during the past several years to assess the validity of simple toxicity tests to predict receiving water impacts of

discharges. Two tests, a 7-day chronic cladoceran reproduction test and a 7-day larval growth fish test have been used as the simple toxicity tests for the comparison. The cladoceran test is a full chronic test whereas the larval growth fish test is an estimator of chronic toxicity.

The eight site studies consisted of on-site effluent tests with both species to determine the NOEL of the effluents, ambient toxicity tests in which water taken from various stream stations was tested for toxicity, a thorough biological survey and effluent dilution and time of flow studies. Predictions of toxic situations based on the toxicity tests are compared to the impact on the community where such exposures occurred to measure the validity of the toxicity tests.

The first report[3] is published and the tests were found to predict well the measured biological effects. Several more of the site study reports are in draft form and in these too the predictions were good. New insights were gained at several of the sites. Such events as spills, upstream toxicity and unsuspected toxicity in apparently well treated wastes were found. Currently, effort is being expended to develop a reliable way to measure the persistence of toxicity to better assess the extent of exposure that might be expected.

Case studies are now being planned to extend the evaluation to include the actual issuance of a permit limit based upon the test data. Toxicity reduction plans are being formulated to aid dischargers in alleviating toxicity problems.

Both for criteria and for toxicity limits, data for a few test species are being used to attempt protection of a community of many species. In the past, the surrogate species concept has generally been in vogue. This concept is

based on the premise that a given test species represents the community in regard to sensitivity to chemicals. One only needs to examine Table 3 in the various criteria documents to conclude that a given species does not have the same sensitivity relative to other species for all chemicals. In spite of this very obvious fact, aquatic toxicologists continue to look for the universally sensitive species much like alchemists looked for the universal solvent. It is certainly true that some of the commonly used test species are often among the more sensitive but unless an error of 25-30% is acceptable, a better method must be found. Current thinking in some EPA labs has taken another approach. The conceptual basis is that in any group of species (such as a community) there will be a range of sensitivity to a given chemical. The objective should be to sample that distribution in order to estimate its range. Since given species are not consistently sensitive, the only way to find the sensitive end of the range is a valid sampling of the distribution. Thus, the objective changes from one of arbitrarily selecting "the most sensitive species" to one of scientifically sampling the distribution to estimate the limits of the sensitive end of the range.

In the criteria document minimum data base, the required data does not specify species but rather representatives of functional or taxonomic groups within the community. For wide scale routine effluent testing, the minimum data base used for criteria documents was felt to be too expensive to require. Since the discharge limits are derived for each discharge, the geographic extent affected by each effluent limit is considerably less than for national criteria and permits are issued for a few years at a time. Therefore, only two or three species are being required. The hydrologic conditions under which the limits are applied are such that only infrequently would permissible concentrations occur. This provides a considerable margin of safety to the limits so derived.

Trends in research activity in the coming years are speculative of course, and can only be based on what appears to be the areas of regulatory emphasis. In no particular order of importance, the following areas appear to be ones that will be emphasized:

1.) Because of the increasing use of aquatic toxicity test data for decision making, shorter and simpler tests to measure especially chronic toxicity will be developed. In this effort, the blanket use of flow-through techniques will diminish and test type (flow-through, static, renewal) will be chosen based on the needed accuracy.

2.) Much effort is likely to be devoted to models of toxicity dispersion and decay from discharges comparable to the work that was formerly done with BOD.

3.) Aquatic toxicologists will strive to include the regulatory strategy into their deliberations in setting acceptable levels in order to make more unform the margin of safety incorporated into water quality and effluent limits.

4.) More attention must be given to methods for integrating effects of variable exposure. The continuous exposure during an organism's lifetime does not represent the types of exposure that actually exist in receiving waters.

5.) Considerable attention needs to be given to how best to select test species for protecting communities and how to apply the data in a more realistic way.

6.) Increasing use of QSAR will occur with associated refinements as a result of research.

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